Sampling and Survey with AUVs in Adverse Weather Conditions

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LONG-TERM GOAL

We wish to investigate the basic and applied problems associated with the efficacious reconnaissance of littoral waters in support of mine warfare and oceanographic tasks. An underlying goal is to strive for cost-effective means to solve these problems.

OBJECTIVES

We wish to address AUV performance issues with respect to navigation, communication, control and conditional mission planning in adverse weather conditions during which the underwater acoustic propagation properties are severely affected by noise, bubble formation, and mixing properties induced by storm fronts.

APPROACH

By capitalizing on the AUV technology, shallow-water oceanographic measurements in adverse weather conditions using multiple AUVs can provide a cost-effective solution in understanding the cause and effect of a storm passage. A number of graduate-level projects have been funded via this grant, to continue building the infra-structure necessary to succesfully pursue the objectives and long term goals of this initiative. We wish to accommodate a prolonged underwater survey during a passing storm, an underwater docking and power station is needed so that AUVs can acquire power recharge and data upload when necessary, address design and implementation problems associated with our current implementation of control software, current docking design and performance in stormy conditions, and lack of acoustic propagation and communication models. The following encompasses the graduate students' projects topics:

AUV High Level Software Control Architecture

The Morpheus, the latest generation of AUV developed at Florida Atlantic University was designed to be as modular as possible, and to handle longer, more complicated missions. The software must now reflect this improvement: it should be as dynamic as possible, must adapt to the different missions and emphasize flexibility and scalability. It must allow for complex behaviors, failure detection and handling and multiple cooperative missions. On the other hand, the new high-level controller has to remain accessible to the non-expert user. To achieve these goals, a new architecture, based on the Convenient Hierarchical Autonomous State Machine formalism, was implemented using Python. The

system is modeled as a set of concurrent processes communicating through shared memory to accommodate a variety of sensor payloads from one mission to the next. New control tools can be integrated dynamically into the architecture in the form of modules implementing new behaviors.

Post Processing Kalman Filter for AUV Navigation

This thesis describes an automated post-processing tool, designed for use on navigational data gathered by AUV, developed and operated by the Department of Ocean Engineering at Florida Atlantic University. The post-processing tool consists of a 9-state complementary Kalman filter in conjunction with a Rauch-Tung-Striebel (RTS) smoothing algorithm. The Kalman filter is run forward in time to merge navigational data from an Inertial Measurement Unit (IMU), a Doppler Velocity Log (DVL), a magnetic compass, a GPS/DGPS system and an Ultrashort Baseline (USBL) tracking system. Subsequently, the RTS smoothing algorithm is run backwards in time to find and compensate for drift errors in dead reckoned position and compass measurement error. The post-processing tool has been implemented as a graphical user interface, designed in MATLAB. Improved accuracy in post-processed position and heading has been verified by conducting sea trials and post-processing the collected data.

Acoustic Ad-Hoc AUV Communication Networks

This thesis presents the design and implementation of an underwater network communication protocol. The goal is to enable several AUVs to form a communication network and to exchange information during at-sea missions. The focus of this work is on the upper layers of the protocol: Network and Transport layers.

Routing is a critical issue since all the nodes forming the network are moving. A study and comparison of existing routing algorithms is presented. Two routing algorithms have been chosen and implemented in the network layer of the protocol: Flooding and Destination Sequence Distance Vector Routing. The protocol has been tested on several types of simulated missions. An analysis of the results is proposed for each mission

Force Sensor System for Real-Time Measurement of Thrust on AUVs

When a control system for an AUV requires thrust, it is common to apply a simplified model to estimate the force generated. Even though this model takes into account several parameters, it will never recover the real value. Our challenge is to directly measure the force, in real time, from the tunnel thrusters used in the positioning control of the Mini AUV known as Morpheus. Therefore, a force sensor system has been designed, optimized, machined and tested that supports the thruster assembly. The sensor implements strain gages to measure the deformation in a beam. To optimize the capabilities of the sensor, a finite elements analysis has been run. The sensor has been fabricated and tested to determine the static and dynamic characteristics. This thesis discusses the design implementation, optimization, fabrication and testing of the force sensor. The discussion begins with an overview of the problem then explains the fabrication, optimization, testing and concludes with recommendation for future work.

Implementation of the Ocean Explorer AUV Dock for Use With the Morpheus AUV

This report highlights important aspects of previous work with the Ocean Explorer (OEX) AUV docking system as a background. This includes short baseline navigation, the Tracking Controller, Mechanical aspects of the dock, and results of testing of the docking system for the OEX. Details of the Morpheus AUV are then given along with the major concerns faced in trying to adapt the OEX dock to the Morpheus. Using computer simulation, the reaction of the Morpheus when it impacts the dock is explored and the results of at sea testing (the collision of the vehicle and the dock) is discussed. A stinger strength analysis of the docking components is included and finally, suggestions for future work including modifications of the existing dock as well as another docking scheme are presented.

WORK COMPLETED

A series of docking tests was performed which included two days of testing with a "dummy" vehicle followed by two days of testing with the real Morpheus. The initial tests were done with the dummy vehicle because the Morpheus was unavailable for docking experiments at the time. These tests were conducted in order to get a better sense of potential problems with the docking system. Additionally, the testing procedure could be refined to some degree. This would help minimize the time necessary to conduct tests with the Morpheus when it became available.

The graduate theses were completed in a timely fashion and these projects require further work by future graduate students. This was the intention for these projects. Other projects were implemented in software and need further testing and code optimization.

RESULTS

The results from the docking tests showed that the dock has a good chance of being a viable design for use with the Morpheus. With the vehicle under power and when the stinger hits the dock within the docking window, the rate of what were considered successful docks was 94%. When implemented with a docking controller on the vehicle that is capable of bringing the vehicle around for another attempt at docking if it misses the dock, this system should be adequately reliable.

We are actively continuing the development of the acoustic Ad-Hoc AUV network and the development of an acoustic propagation model to serve as the physical model for the proposed acoustic real-time simulator to ONR in June 2001, amongst other components for this proposal.

IMPACT/APPLICATION

The sampling and survey with AUVs in adverse weather conditions provide a fertile ground for further development and refinement of AUV technology and related projects. These projects include the acoustic real time model proposed to ONR during the summer 2001.

TRANSITIONS

None

RELATED PROJECTS

- Very Shallow Water Mine Reconnaissance with Multiple AUVs
- Multiple Vehicle Sampling and Survey for MCM
- Node-Based Adaptive Sampling & Advanced AUV Capabilities.

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